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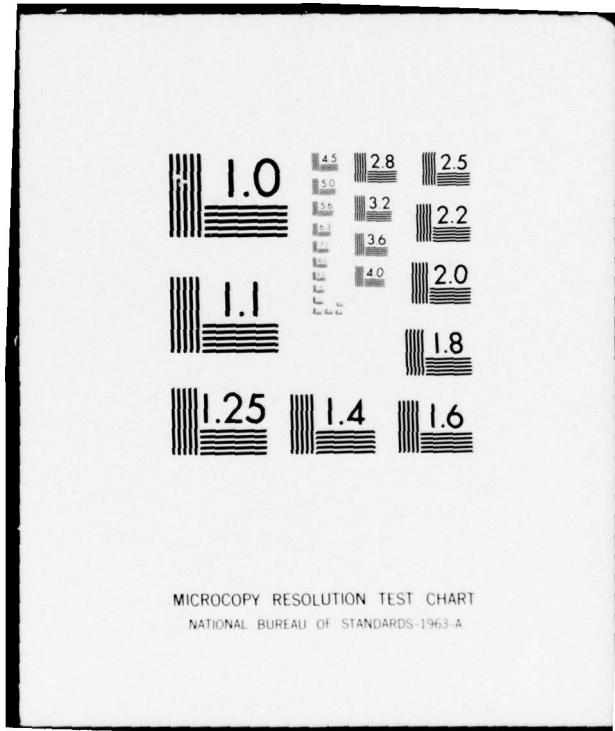
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⑩ Stanley A. Horowitz
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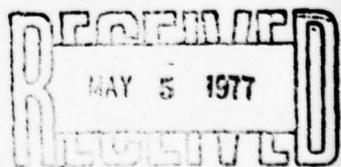
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THE CHARACTERISTICS OF NAVAL PERSONNEL AND PERSONNEL PERFORMANCE

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ABSTRACT

The productivity of enlisted personnel aboard ships is measured as a function of their personal characteristics. Ship readiness as measured by the material condition of shipboard equipment, depends on the size and composition of a ship's crew, the complexity of equipment, and other factors. The productivity of enlisted personnel varies systematically with high school graduation, entry test scores, paygrade, experience, Navy training, race, and marital status. The importance of particular factors varies by occupation. More complex equipment is in worse condition and requires higher quality personnel. Ship age and overhaul frequency also affect material condition. Implications are drawn for policies regarding recruitment, retention, manning, rotation, and pay.

INTRODUCTION

The efficiency of Navy personnel policies can only be judged by the contribution of personnel to the effectiveness of the fleet. This contribution is very elusive. Thus, little is known about the relative value of personnel who differ in such characteristics as education, experience, mental ability, and training in the Navy.

Proper allocation of Navy personnel requires that variations in productivity among individuals reflect variations in their cost. Thus, knowledge of how personnel differences are likely to contribute to effectiveness differences is necessary for rigorous analysis of Navy decisions regarding the level of manning, recruitment,

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assignment, rotation, and pay. Currently these decisions usually reflect reasonable assumptions about what kinds of people are most suitable for what jobs.

This paper is an effort to improve personnel management and fleet readiness by focusing on the contribution of shipboard personnel to the material condition of equipment. If we are successful in attributing variations among ships in the level of maintenance to differences in crew members responsible for maintenance, we will have made an important step toward more informed analysis of defense manpower issues.

The study addresses a wide range of questions. Among the main ones are:

- o How valuable are different kinds of enlisted personnel in various maintenance occupations?
- o How could personnel policies be changed to improve the material condition of the fleet?

Although we focus primarily on personnel-related determinants of shipboard material condition, other questions are also dealt with in order to comprehensively examine the material condition of ships:

- o What is the contribution of more frequent overhauls to material condition?
- o How much worse is the condition of older ships?
- o How does equipment complexity affect material condition?

And, a related question:

- o Are high quality enlisted personnel more valuable in dealing with more complex equipment?

The answers to these questions indicate that fleet material condition can be improved by revised personnel policies.

We found that the productivity of enlisted personnel is a function of their characteristics. In general men in higher pay-grades and men with more experience are more productive. High school graduation and entry test scores often predict performance. Training received in the Navy often enhances productivity. Older ships are in worse material condition, and lengthening the over-haul cycle degrades material condition.

The precise nature of the relationship between individual characteristics and productivity varies widely across enlisted occupations (or ratings). It also depends on the complexity of the equipment being maintained. Not only is complex equipment in worse condition, it requires more skilled men to maintain it. On the other hand, simpler equipment was found to benefit more from larger crews.

A MODEL OF THE MATERIAL CONDITION OF SHIPS

The amount of time that equipment fails to function in a specified time period can be expected to depend on the kind of equipment, the age of the ship, length of time since the ship was last overhauled, and manning. We use regression analysis to estimate the relationship between downtime due to shipboard equipment failures and its hypothesized determinants.

We have confined our examination to cruisers and destroyers: 40 destroyers (DDs), 18 guided missile destroyers (DDGs), 17 frigates (FFs), 4 guided missile frigates (FFGs) and 12 cruisers (CGs). These 91 ships are all the active ships of these types that underwent overhauls in fiscal years 1972, 1973, and 1974. To be sure that we were looking at comparable periods on all the ships, the entire period from one overhaul to a ship's next overhaul was considered.¹

Whenever a ship suffers an equipment failure that degrades its operational capability, it must file a casualty report (CASREPT). We have used CASREPT information to derive measures of maintenance effectiveness.² CASREPT downtime per month is our key measure of shipboard material condition.³ CASREPT downtime is the number of casualties a ship had multiplied by the average time CASREPTs on that ship took to be fixed. CASREPT downtime per month is proportional to the average number of CASREPTs outstanding.

¹The data we used on equipment failure were not available before 1970. Thus, we weren't able to look at the entire inter-overhaul period for some of the ships. At least 18 months of data were available for all the ships. We assume that the material condition of a ship is not a major factor in determining when it is overhauled.

²CASREPT information is kept on an automated file system at the Navy Fleet Material Support Office (FMSO) in Mechanicsburg, Pa.

³We also examined data on material condition derived from 3-M corrective maintenance reports, overhaul departure reports, and INSURV reports (reports of the Board of Inspection and Survey).

Rather than study the determinants of CASREPT downtime for entire ships, we concentrated on several sub-systems. These sub-systems were chosen because they are common to a large number of cruisers and destroyers, and are maintained by men in a small number of ratings. The sub-systems are boilers, engines, gun systems, missile systems, anti-submarine warfare (ASW) systems, and sonars. Table 1 shows the ratings of the personnel who are responsible for the maintenance of these sub-systems.

TABLE 1
SUB-SYSTEMS STUDIED

<u>Sub-system</u>	<u>Associated Rating</u>
Boilers	Boiler Technician (BT)
Engines	Machinist's Mate (MM)
Gun Systems	Fire Control Technician (FT) Gunner's Mate (GM)
Missile Systems	Fire Control Technician (FT) Gunner's Mate (GM)
ASW Systems	Gunner's Mate (GM) Sonar Technician (ST) Torpedoman's Mate (TM)
Sonars	Sonar Technician (ST)

As the table shows, the same ratings are sometimes responsible for part of the maintenance of more than one sub-system. To properly match men and equipment, we allocated CASREPTs both by rating and by sub-system.¹

The enlisted manning characteristics examined for our designated ratings are shown in table 2. The bulk of the personnel analysis in this paper relies on crew histories compiled from the Navy's Enlisted Master Record (EMR). To build these histories, we reviewed the records of the entire enlisted force for seven years between 1967 and 1975, and picked out the men on the 91 ships. We then developed aggregate statistics describing the characteristics of each crew by rating. This required weighting the characteristics

¹This allocation was accomplished by referring to the Equipment Identification Code (EIC) associated with each CASREPT.

of individuals by the fraction of the observation period they were assigned to the ship.¹

TABLE 2
SHIP ENLISTED MANNING CHARACTERISTICS STUDIED^a

Number of enlisted personnel
Pre-Navy education
Entry test scores
Paygrade profile
Length of service (LOS)
Time aboard this ship
Time at sea
Navy schooling
Specialized qualifications
Race
Marital status

^aData were also gathered on the age of enlisted men and on the number of officers aboard the ships. These factors did not prove to be important.

The level of CASREPT downtime should vary inversely with the number of enlisted personnel. Men with more pre-Navy education and higher entry test scores in relevant areas ought to do better maintenance. We expect more experienced men to be more productive than less experienced men, and men in higher paygrades to be more productive than men in lower paygrades. Since more experienced men are more likely to have higher rank, an analysis which focused only

¹When characteristics changed during an individual's tour aboard one of the ships (e.g., LOS, paygrade), the change was taken into account. In many cases, we couldn't tell when men left the ships because they left the Navy and were not observed on subsequent EMRs. People who have been out of the Navy for six months are deleted from the EMR. Since there are one and two year gaps between the EMRs that we used, many men were dropped from the record before we observed them, it was necessary to approximate their departure dates from information on when they were likely to have left the Navy. In rare cases, information on personnel aboard DDs was taken from semi-annual Bureau of Naval Personnel Enlisted Distribution and Verification Reports (BuPers Form 1080). Use of these data will be identified in context.

on rank, for example, would be unable to determine how much of the added productivity of senior men reflected selection of the best men for promotion and how much was merely the result of experience. By including both paygrade and LOS in the analysis, we will be able to disentangle the quality dimension of higher paygrade from the effect of experience. We will not assume that more experienced (or higher ranked) men continuously get better at their jobs. We will examine the possibility that after a break-in period junior men reach a higher level of proficiency beyond which they tend not to improve, or that further significant improvement only occurs after a considerable time.¹ Our estimates of the relationships between rank, LOS and productivity will allow an alternative to the assumption that the pay of different kinds of enlisted men reflects differences in their productivity.²

Experience at sea may be more important in increasing the productivity of enlisted men than shore duty. We will examine whether men with more prior sea duty tend to have ships with less CASREPT downtime. We also will see whether ships with more stable crews, those whose men have been aboard longer, have less downtime. If either of these variables reflects higher productivity, the Navy's policy regarding sea-shore rotation will be open to question.

The completion of more Navy courses should lead to higher productivity, and thus to better maintenance.

The acquisition of certain advanced skills confers Navy Enlisted Classifications (NECs) on individuals. Some NECs can be gained only via school attendance; others can be earned on the job. We differentiated between these two types, and used the number of NECs of each type that men possessed as a measure of the extent of advanced training.

The impact of the race variable, the percent of the crew that is black, is not predictable, but its inclusion is nonetheless appropriate. If blacks receive lower quality educations, more blacks, holding educational attainment constant, may be associated with

¹Continuous linear and logarithmic forms were tried for the LOS variable. Then men were divided into eight LOS groups: under 1 year, 1-2 years, 2-3 years, 3-4 years, 4-5 years, 5-7 years, 7-10 years, and over 10 years. These classes were then aggregated to find the relationship that best predicted downtime. A similar aggregation procedure was used for paygrades.

²This assumption is used fairly widely. See, for instance, "Formal and On-the-Job Training for Navy Enlisted Occupations," by R. Weiher and S. Horowitz, CNA Professional Paper 83, November 1971.

worse maintenance. If the Navy's entry tests discriminate against blacks, more blacks, holding test scores constant, may be associated with better maintenance. We hope to discover whether the Navy's use of high school graduations and of entry tests as guides to recruitment and assignment is equally appropriate for blacks and whites.

We are also unable to predict how marital status correlates with the productivity of enlisted men. Married men may be more stable and more serious workers, and hence more productive. On the other hand, some married men may dislike sea duty a great deal. This disaffection may make them less productive.

For each of nine groups (BT, MM, GM, FT, TM, ST, guns, missiles, ASW) we estimated a relationship for CASREPT downtime per month as a function of ship age, length of time between overhauls, equipment complexity, and the crew characteristics listed in table 2.1. Ships are the units of observation in the analysis.

It was expected that newer ships would, other things equal, have less CASREPT downtime.

A longer gap between overhauls should lead to more equipment downtime. If it does not, ships are being overhauled too frequently.

Ships vary to some extent in their equipment. Usually these differences correspond to ship type or class differences; sometimes they do not. Obviously this may influence ships' maintenance histories. For instance, the 1200-pound boilers on some ships have had more problems than the older 600-pound type because of technical innovations in their design. In general, more complex equipment is expected to be down more often. Because of the differences between these two types of boilers, we allowed for the possibility that personnel contributions to the maintenance of boilers were different

¹We also examined the connection between operating tempo and material condition. No direct connection was found. In addition, the relative condition of ships based on the east and west coasts was examined. The west coast ships appeared to have less CASREPT downtime (they also steamed significantly more). Finally, using a procedure for looking at all our ratings simultaneously, we checked for whether there were systematic tendencies for some ships to be better than others in all areas. In some cases there were. Inclusion of these operating tempo, coast and ship variables did not have a large effect on the impact of other variables on CASREPT downtime, thus we have concentrated on the results of estimating the formulation described.

for ships with 600-pound plants and 1200-pound plants.¹ Equipment variations for the sub-systems will be discussed along with the empirical results.

We estimated the relationship using ordinary least squares. As was noted earlier, the period of observation for the dependent variables was either the entire time between a ship's overhaul in FY 72, 73, or 74 and its previous overhaul, or as much of this period as possible (always at least eighteen months before the more recent overhaul). For the explanatory variables, the entire inter-overhaul period was used. The condition of a piece of equipment depends not only on the care it is getting now, but also on the care it received in the past. This is why we've used such a long observation period, and why it seemed desirable to use a longer observation period for the explanatory variables than for downtime when the complete CASREPT data set was not available. We hoped to capture the long-run effects of variation in the determinants of maintenance effectiveness. The next section discusses the results of our estimations.

EMPIRICAL RESULTS

In this section the results of our estimations will be treated.² Due to extremely severe space constraints, only one of the relationships, that for boilers, will be discussed in detail. A summary of results will also be presented.³ The explanatory variables differ across groups because variables that did not improve the prediction of CASREPT downtime per month were deleted.

Boilers

For the most part, the ships have one of four kinds of propulsion plants. All of the DDs in the Forrest Sherman Class, all the DDGs, and all the CGs have 1200 pound per square (p.s.i.) main propulsion plants and two screws. The older DDs also have two screws, but 600 p.s.i. plants. The FF 1052 class has one screw

¹This was done by multiplying each personnel variable by both a 600-pound ship dummy and a dummy for ships with 1200-pound plants. The two variables were entered separately into the relationship being estimated. If this procedure did not improve the explanatory power, the results were discarded.

²Both linear and semi-logarithmic forms for the regressions were tested. The functional form that predicted best for a group is the one used.

³A more complete presentation of results appears in "Personnel Performance and Ship Condition," CNS 1090, 31 March 1977, and is available from the authors upon request.

and 1200 p.s.i. plants, while the FF 1040 (Garcia) class and FFGs have one screw and pressure-fired boilers.¹ Distinguishing among these kinds of systems proved to be very important in explaining the material condition of boilers as measured by CASREPT downtime.

Table 3 lists the CASREPT downtime for different kinds of plants. The more complicated 1200 p.s.i. plants obviously have more boiler trouble than 600 p.s.i. plants. Because boiler down-times for the two types of one-screw plants were similar, they have been treated together in the rest of the analysis.

TABLE 3
CASREPT DOWNTIME FOR BOILERS

<u>Ship classes or types</u>	<u>Number of ships</u>	<u>Kind of equipment</u>	<u>Average CASREPT downtime (hrs/mo)</u>
			<u>Boilers</u>
CG, DDG, Forrest Sherman destroyers (except DD 933)	36	2 screws, 1200 p.s.i.	730 ^a
FRAM destroyers	33	2 screws, 600 p.s.i.	218
FF 1040, FFG 1	11	1 screw, pressure fired	318
FF 1052	8	1 screw, 1200 p.s.i.	301

^a730 is approximately the number of hours a month. This means that, on the average, these ships have one boiler CASREPT outstanding. Since they have two boilers, one is usually CASREPT-free. In any case, existence of a CASREPT does not necessarily imply complete inability to operate. 75 percent of all CASREPT downtime is C-2, implying minor degradation of mission-essential equipment. If equipment is C-3 it is termed marginally ready. C-4 means not ready. In this study all three types of CASREPTs have been aggregated together.

¹The 91 ships include one diesel-powered ship, one 600 p.s.i. ship with one screw, and one Forrest Sherman ship without automatic combustion control. All three ships were deleted from the BT analysis.

The predictive relationships estimated for equipment maintained by BTs are displayed in table 4. The coefficients are the best estimates of the impact of a one-unit change in each of the explanatory variables on the average number of hours of boiler CASREPT downtime per month. These results are never in an unexpected direction and are often quite significant.

Ships with two-screw, 1200 p.s.i. plants had much more downtime than other ships.¹ Not only did equipment complexity affect material condition, it also affected the impact of the crew on material condition. Crew quality, as measured by entry test scores, paygrade, training, and length of service, seems to have mattered much more on 1200 p.s.i. ships, particularly those with two screws. We estimate that an increase of one percentage point in the average Shop Practices Test scores of BTs on two-screw, 1200 p.s.i. ships would lower CASREPT downtime by an average of 138 hours per month. There is also a very high payoff to having rated personnel. A one percentage point drop in the fraction of BTs who are unrated (E-3 or below) is associated with a drop of 25.19 hours in CASREPT downtime per month. Married BTs are less productive than single BTs on two-screw, 1200 p.s.i. ships. Perhaps they are less willing to put in the long hours the job requires. Training was important on one-screw ships, though not as important as on two-screw, 1200 p.s.i. ships. If a quarter of the BTs attend one extra school, CASREPT downtime is estimated to fall by 72 hours a month (1/4 times 287) on the one-screw ships. Variations in crew size, on the other hand, appeared more important on 600 p.s.i. ships. Addition of an extra BT could be expected to decrease downtime by 71 hours per month.²

¹The coefficient of 7924 does not mean that two-screw, 1200 p.s.i. ships have on average 7924 more hours of downtime a month than other ships. In cases like this, where different coefficients are estimated for different types of equipment, or where the characteristics that enter the predictive relationship differ by equipment type, one cannot look at the coefficient of an equipment-type dummy variable as reflecting the differential downtime of that kind of equipment. To derive the average difference in downtime per month by equipment type, one must use the entire relationship to estimate average downtimes for different kinds of equipment at reasonable values of the independent variables. A comparison of the numbers in the third column of table 3 gives a good indication of the impact of equipment complexity on the material condition of boilers.

²The data underlying the crew size variable used here came from BuPers Form 1080. We gathered these data only for the DDs in the sample. Perhaps if we had had them for all 88 ships in this analysis, crew size would have appeared more important for the 1200 p.s.i. ships. (There were six 1200 p.s.i. DDs in this sample.)
(Footnote continued)

TABLE 4
DETERMINANTS OF MATERIAL CONDITION FOR BOILERS
(CASREPT downtime, hours per month)

<u>Explanatory variable</u>	<u>Coefficient</u>	<u>t-value</u>
Personnel variables		
On two-screw, 1200 p.s.i. ships		
Average score on Shop Practices Tests	- 1.38	- 3.34 ^c
Percent of BTs who are E-3 or below	25.19	3.00 ^c
Percent of BTs who are E-8 or above	- 34.06	- 1.19 ^b
Percent of BTs with under one year in the Navy	35.65	2.50 ^b
Average number of school-related NECs per BT	-1586	-4.26 ^c
Percent of BTs who are single	- 23.20	- 3.29 ^c
On one-screw ships		
Average number of Navy schools attended by BTs	- 287	- 1.87 ^a
On two-screw, 600 p.s.i. ships		
Average number of BTs	- 71	- 3.72 ^c
On all ships		
Percent of BTs with under 10 years in the Navy	8.94	1.29
Non-personnel variables		
Equipment complexity		
Two-screw, 1200 p.s.i. plant	7924	3.60 ^c
Logarithm of ship age (years)	515	3.22 ^c
Constant	Corrected $R^2 = .52$ Degrees of freedom = 76	- 635

^a Significant at the 10 percent level.

^b Significant at the 5 percent level.

^c Significant at the 1 percent level.

These results do not mean that crew size makes no difference on 1200 p.s.i. ships or that Navy training makes no difference on 600 p.s.i. ships. They do mean that variations in these characteristics within the ranges observed in the fleet are not likely to make much difference.

Not surprisingly, we found that, other things equal, older ships had significantly more boiler problems.

SUMMARY OF RESULTS

The material condition of shipboard equipment is affected by the complexity and age of the equipment, the length of time since it was overhauled, and the number and characteristics of the men who operate and maintain it. Crew characteristics that influence the productivity of enlisted men include high school graduation, entry test scores, race, marital status, length of service, pay-grade, sea experience, and advanced training. Not all of these factors make a difference for all kinds of equipment, but in all cases some of them matter.

Our empirical results are summarized in table 5. It displays the characteristics that we have found to influence the productivity of men in each of the six ratings we examined. It also shows other factors that affected the material condition of equipment handled by men in each of the ratings. An "X" signifies a relationship that was unexpected; a check means that it was not. A blank means that no relationship was found.¹

Equipment complexity is an important factor in the condition of all kinds of equipment.

In all cases, men in higher paygrades are more productive than their juniors, even when length of service is held constant. Except for TMs, some measure of LOS related positively to productivity. For STs, sea duty is the only kind of experience that was found to increase productivity. Sea duty also is important in several other ratings.

² (Continued from previous text page) Using crew size data from the Enlisted Master Record no crew size effect was found. Usually the EMR and 1080 form measures of crew size correlated quite highly (an average of .67). For BTs, the only rating for which 1080 Form data were used, the correlation was only .48.

¹ In the rare cases where we found a relationship in a sub-system equation (guns, missiles, or ASW) that was not in the corresponding rating equation, it was assigned to the relevant rating in table 5. Some of these estimated effects are more statistically reliable than others.

TABLE 5

DETERMINANTS OF PERSONNEL PRODUCTIVITY AND EQUIPMENT CONDITION
AS MEASURED BY CASREPT DOWNTIME

<u>Crew characteristics or other determinant of material condition</u>	<u>BT</u>	<u>MM</u>	<u>GM</u>	<u>FT</u>	<u>TM</u>	<u>ST</u>
Crew size	✓	✓		✓	✓	
High school graduation				✓		✓
Entry test scores	✓		✓	✓		
Paygrade	✓	✓	✓	✓	✓	✓
Length of service	✓	✓	✓	✓	X	
Sea experience{ aboard prior ships		✓	✓			✓
aboard current ship	✓					
Training{ number of schools attended	✓	X	X		✓	✓
number of NECs attained	✓	✓	✓			
Marital status	✓					✓
Race					✓	
Ship age	✓	✓			✓	
Time between overhauls				✓	✓	✓
Equipment complexity	✓	✓	✓	✓	✓	✓

Our results regarding paygrade and experience must be interpreted carefully. They mean that men who get promoted are more productive than men who do not under existing promotion policies. They do not mean that more men should be promoted. The mere act of promotion does not make men more valuable.

In calculating productivity differences for men with different lengths of service one must take account of other factors that differ with LOS. For example, men who have been in the Navy ten years are likely to be in higher paygrades than men who have been in five years. The probability of promotion and the estimated additional productivity of men in higher paygrades must be taken into account in comparing the value of men with different lengths of service.

FTs and STs are more productive when they are high school graduates. In other, less technical, ratings high school graduates were not estimated to be more productive than other men of the same paygrade and LOS. Entry test scores predict the performance of BTs, GMs, and FTs.

Variations in productivity reflected variations in training in all of our ratings except for FTs. Perhaps all FTs are so highly trained that variations do not matter much. When paygrade and LOS are held constant, however, additional school attendance helped MMs and GMs only if it led to attainment of an NEC. Interestingly, these were two ratings where sea experience was more valuable than shore duty in increasing men's productivity. Some of the value of training may have been picked up by paygrade variables. This will be the case if some men benefit from training and others do not, and if those who benefit are more likely to be promoted. We recommend extreme caution in using our results to draw negative conclusions about the value of training.

Single STs and BTs were estimated to be more productive than married men in those ratings.

Entry tests may discriminate against black FTs, who are more productive than expected on the basis of test scores and high school graduation. This effect was not found in other ratings.¹

Older ships have more CASREPT downtime, particularly in engineering. Longer gaps between overhauls lead to more downtime in half of the ratings studied.

Table 5 misses some important facets of our results. Frequently, higher skill levels reflected in education, test scores, experience, or training increased productivity only when men handled relatively complex equipment. On the other hand, variations in crew size seemed to make the most difference on simpler ships.

CONCLUSIONS

We have answered most of the questions posed at the beginning of this paper. We have estimated the relative value of different kinds of enlisted personnel in different occupations, and shown how material condition could be improved. We have quantified the effects of ship age, overhaul policy, and equipment complexity on the ability of ships to perform their missions.

Our results have implications for what policies should be followed to improve the management of enlisted personnel. In many cases discovery of the precise nature of these implications requires calculation of the cheapest way to improve material condition. This, in turn, requires that our estimates of productivity differences

¹CNA Study 1039, "Enlisted Selection Strategies," by R.F. Lockman, found that entry tests are relatively poor predictors of the success of blacks in electronics schools in the Navy (p. 10).

be combined with estimates of differences in the cost of personnel with various levels of education, ability, experience, and training.

In other cases the policy implications of our results are apparent without future analysis.

- o Place a higher proportion of senior men and highly trained men on ships with complex equipment.
- o Pay more attention to the level of manning on ships with less complex equipment. We would not recommend manning cuts where we found no impact of crew size because maintenance is not the only task men have.
- o Do not screen men so carefully on the basis of high school graduation and entry test scores in ratings where these characteristics do not seem to increase productivity.
- o Try to get sonar technicians to spend more time at sea. Paying special sea pay selectively to certain ratings should be considered.
- o Although higher entry test scores do not always indicate higher productivity, they usually do not seem to discriminate against blacks. Fire control technicians are an exception. Perhaps blacks should be given waivers to become fire control technicians even if they do not quite meet the usual criteria.
- o The current Navy data system is better for measuring material condition than many people believe. We have found reasonable relationships using the data.
- o More attention should probably be paid to the maintenance implications of introducing complex new equipment.
- o The Navy's policy of paying married men more than single men should be re-examined. Currently housing allowances and other benefits (exchange privileges, medical care) favor married men. Wherever we found a difference in productivity between single and married men, it was the single men who were better.

We found that the correlates of individual productivity and of sub-system material condition vary widely from rating to rating and from sub-system to sub-system. We have actually estimated relationships that have merely been asserted in the past. This study is the first we know of to go beyond the assumption that the relative value of men with different paygrades and lengths of service

is measured by the ratio of their salaries. We know of no other statistical evidence that encouraging continuation at sea is important (aside from the possibility of cutting out superfluous shore billets). Also, there are few other indications that overhauls really do improve the subsequent condition of ships, and some work that calls the assumption into question.

By concentrating on CASREPT downtime as the measure of the condition of shipboard equipment, we have derived estimates that are relevant primarily for predicting changes in CASREPT downtime. Such changes may not correlate with other measures of material condition or operational capability, although they are correlated with both inspection results and records of 3-M corrective maintenance actions. In any case, CASREPTs are probably the best available information on ships' inability to perform their missions.

We feel strongly that efficient operation of the Navy requires quantitative links between the inputs that the Navy buys and the performance it delivers. This paper is one of the first such links for ship operations.

CNA Professional Papers — 1973 to Present*

PP 103

Friedheim, Robert L., "Political Aspects of Ocean Ecology" 48 pp., Feb 1973, published in *Who Protects the Oceans*, John Lawrence Hargrove (ed.) (St. Paul: West Publ'g Co., 1974), published by the American Society of International Law) AD 757 936

PP 104

Schick, Jack M., "A Review of James Cable, *Gunboat Diplomacy: Political Applications of Limited Naval Forces*," 5 pp., Feb 1973. (Reviewed in the *American Political Science Review*, Vol. LXVI, Dec 1972)

PP 105

Corn, Robert J. and Phillips, Gary R., "On Optimal Correction of Gunfire Errors," 22 pp., Mar 1973, AD 761 674

PP 106

Stoloff, Peter H., "User's Guide for Generalized Factor Analysis Program (FACTAN)," 35 pp., Feb 1973, (Includes an addendum published Aug 1974) AD 758 824

PP 107

Stoloff, Peter H., "Relating Factor Analytically Derived Measures to Exogenous Variables," 17 pp., Mar 1973, AD 758 820

PP 108

McConnell, James M. and Kelly, Anne M., "Supernova Naval Diplomacy in the Indo-Pakistani Crisis," 14 pp., 5 Feb 1973, (Published, with revisions, in *Survival*, Nov/Dec 1973) AD 761 675

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Berghofer, Fred G., "Salaries—A Framework for the Study of Trend," 8 pp., Dec 1973, (Published in *Review of Income and Wealth*, Series 18, No. 4, Dec 1972)

PP 110

Augusta, Joseph, "A Critique of Cost Analysis," 9 pp., Jul 1973, AD 766 376

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Herrick, Robert W., "The USSR's 'Blue Belt of Defense' Concept: A Unified Military Plan for Defense Against Seaborne Nuclear Attack by Strike Carriers and Polaris/Poseidon SSBNs," 18 pp., May 1973, AD 766 375

PP 112

Ginsberg, Lawrence H., "ELF Atmosphere Noise Level Statistics for Project SANGUINE," 29 pp., Apr 1974, AD 786 969

PP 113

Ginsberg, Lawrence H., "Propagation Anomalies During Project SANGUINE Experiments," 5 pp., Apr 1974, AD 786 968

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Rehm, Allan S., "An Assessment of Military Operations Research in the USSR," 19 pp., Sep 1973, (Reprinted from *Proceedings*, 30th Military Operations Research Symposium (U), Secret, Dec 1972) AD 770 116

PP 117

McWhite, Peter B. and Ratliff, H. Donald,* "Defending a Logistics System Under Mining Attack,"** 24 pp., Aug 1976 (to be submitted for publication in *Naval Research Logistics Quarterly*), presented at 44th National Meeting, Operations Research Society of America, November 1973, AD A030 454

*University of Florida.

**Research supported in part under Office of Naval Research Contract N00014-68-0273-0017

PP 118

Barfoot, C. Bernard, "Markov Duels," 18 pp., Apr 1973, (Reprinted from *Operations Research*, Vol. 22, No. 2, Mar-Apr 1974)

PP 119

Stoloff, Peter and Lockman, Robert F., "Development of Navy Human Relations Questionnaire," 2 pp., May 1974, (Published in *American Psychological Association Proceedings*, 81st Annual Convention, 1973) AD 779 240

PP 120

Smith, Michael W. and Schrimper, Ronald A.,* "Economic Analysis of the Intractability Dispersion of Criminal Activity," 30 pp., Jun 1974, (Presented at the Econometric Society Meetings, 30 Dec 1973) AD 780 538

*Economics, North Carolina State University.

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Devine, Eugene J., "Procurement and Retention of Navy Physicians," 21 pp., Jun 1974, (Presented at the 49th Annual Conference, Western Economic Association, Las Vegas, Nev., 10 Jun 1974) AD 780 539

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Kelly, Anne M., "The Soviet Naval Presence During the Iraq-Kuwaiti Border Dispute: March-April 1973," 34 pp., Jun 1974, (Published in *Soviet Naval Policy*, ed. Michael McCawire; New York: Praeger) AD 780 592

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Petersen, Charles C., "The Soviet Port-Clearing Operation in Bangladesh, March 1972-December 1973," 35 pp., Jun 1974, (Published in *Michael McCawire, et al. (eds) Soviet Naval Policy: Objectives and Constraints*, (New York: Praeger Publishers, 1974) AD 780 540)

PP 124

Friedheim, Robert L. and Juhn, Mary E., "Anticipating Soviet Behavior at the Third U.N. Law of the Sea Conference: USSR Positions and Dilemmas," 37 pp., 10 Apr 1974, (Published in *Soviet Naval Policy*, ed. Michael McCawire; New York: Praeger) AD 783 701

PP 125

Weinland, Robert G., "Soviet Naval Operations—Ten Years of Change," 17 pp., Aug 1974, (Published in *Soviet Naval Policy*, ed. Michael McCawire; New York: Praeger) AD 783 962

PP 126 — Classified.

PP 127

Dragich, George S., "The Soviet Union's Quest for Access to Naval Facilities in Egypt Prior to the June War of 1967," 64 pp., Jul 1974, AD 786 318

PP 128

Stoloff, Peter and Lockman, Robert F., "Evaluation of Naval Officer Performance," 11 pp., (Presented at the 82nd Annual Convention of the American Psychological Association, 1974) Aug 1974, AD 784 012

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Holen, Arlene and Horowitz, Stanley, "Partial Unemployment Insurance Benefits and the Extent of Partial Unemployment," 4 pp., Aug 1974, (Published in the *Journal of Human Resources*, Vol. IX, No. 3, Summer 1974) AD 784 010

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Dismukes, Bradford, "Roles and Missions of Soviet Naval General Purpose Forces in Wartime: Pro-SSBN Operation," 20 pp., Aug 1974, AD 786 320

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Weinland, Robert G., "Analysis of Gorshkov's Navies in War and Peace," 45 pp., Aug 1974, (Published in *Soviet Naval Policy*, ed. Michael McCawire; New York: Praeger) AD 786 319

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Goudreau, Kenneth A.; Kuzmack, Richard A.; Wiedemann, Karen, "Analysis of Closure Alternatives for Naval Stations and Naval Air Stations," 47 pp., 3 Jun 1975 (Reprinted from "Hearing before the Subcommittee on Military Construction of the Committee on Armed Services," U.S. Senate, 93rd Congress, 1st Session, Part 2, 22 Jun 1973)

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CNA Professional Papers — 1973 to Present (Continued)

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Mahoney, Robert and Druckman, Daniel*, "Simulation, Experimentation, and Context," 36 pp., 1 Sep 1975, (Published in Simulation & Games, Vol. 6, No. 3, Sep 1975)

*Mathematica, Inc.

PP 141

Mizrahi, Maurice M., "Generalized Hermite Polynomials,"* 5 pp., Feb 1976 (Reprinted from the Journal of Computational and Applied Mathematics, Vol. 1, No. 4 (1975), 273-277).

*Research supported by the National Science Foundation

PP 142

Lockman, Robert F., Juhn, Christopher, and Shughart, William F., II, "Models for Estimating Premature Losses and Recruiting District Performance," 36 pp., Dec 1975 (Presented at the RAND Conference on Defense Manpower, Feb 1976; to be published in the conference proceedings) AD A 020 443

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Horowitz, Stanley and Sherman, Allan (LCDR, USN), "Maintenance Personnel Effectiveness in the Navy," 33 pp., Jan 1976 (Presented at the RAND Conference on Defense Manpower, Feb 1976; to be published in the conference proceedings) AD A 021 581

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Squires, Michael L., "Counterforce Effectiveness: A Comparison of the Tsipis "K" Measure and a Computer Simulation," 24 pp., Mar 1976 (Presented at the International Study Association Meetings, 27 Feb 1976) AD A 022 591

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Kelly, Anne M. and Petersen, Charles, "Recent Changes in Soviet Naval Policy: Prospects for Arms Limitations in the Mediterranean and Indian Ocean," 28 pp., Apr 1976, AD A 023 723

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Horowitz, Stanley A., "The Economic Consequences of Political Philosophy," 8 pp., Apr 1976 (Reprinted from Economic Inquiry, Vol. XIV, No. 1, Mar 1976)

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*Research supported by the National Science Foundation

PP 153

Mizrahi, Maurice M., "WKB Expansions by Path Integrals, With Applications to the Anharmonic Oscillator,"* 137 pp., May 1976 (Submitted for publication in Annals of Physics). AD A 025 440

*Research supported by the National Science Foundation

PP 154

Mizrahi, Maurice M., "On the Semi-Classical Expansion in Quantum Mechanics for Arbitrary Hamiltonians," 19 pp., May 1976 (To appear in the Journal of Mathematical Physics) AD A 025 441

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Squires, Michael L., "Soviet Foreign Policy and Third World Nations," 26 pp., Jun 1976 (Prepared for presentation at the Midwest Political Science Association meetings, Apr 30, 1976) AD A 028 388

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McConnell, James M., "The Gorshkov Articles, The New Gorshkov Book and Their Relation to Policy," 93 pp., Jul 1976 (To be printed in Soviet Naval Influence: Domestic and Foreign Dimensions, ed. by M. McGwire and J. McDonnell; New York: Praeger) AD A 029 227

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Wilson, Desmond P., Jr., "The U.S. Sixth Fleet and the Conventional Defense of Europe," 50 pp., Sep 1976 (Submitted for publication in Adelphi Papers, I.I.S.S., London) AD A 030 457

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CNA Professional Papers — 1973 to Present (Continued)

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Horowitz, Stanley A. and Sherman, Allan, "The Characteristics of Naval Personnel and Personnel Performance," 16 pp. April 1977 (To be presented at the NATO Conference on Manpower Planning and Organization Design, Stresa, Italy, 20 June 1977)

PP 181

Mizrahi, Maurice M., "On The Semiclassical Expansion in Quantum Mechanics For Arbitrary Hamiltonians," 6 pp., April 1977. (Published in Journal of Mathematical Physics, Vol. 18, No. 4, April 1977)